Pilot Handbook of Aeronautical Knowledge

Chapter 5: Aircraft Systems.

A) Powerplant

- **a. Engine and propeller**
  - i. Produces thrust
  - ii. Propels A/C and drives systems (electrical, vacuum, etc.)
- **b. Reciprocating Engine**
  - i. Back-and-forth movement of pistons
  - ii. Mechanical energy needed to accomplish work.
  - iii. Two types of classifications
    1. By cylinder arrangement
       - a. V-type, radial, inline, horizontally opposed
    2. Method of cooling
       - a. Liquid or air cooled
  - iv. Horizontally opposed engines are the most popular in GA.
    1. Even # of cylinders
    2. Air cooled
    3. Higher power-to-weight ratio
    4. Streamline install with min drag
  - v. Parts:
    1. Cylinders (valves, plugs, pistons)
    2. Crankcase (crankshaft, connecting rods)
    3. Accessory housing (magnetos)
  - vi. Basic Principles:
    1. Converts chemical energy to mechanical energy
    2. 4 strokes
       - a. Intake
       - b. Compression
       - c. Power
       - d. Exhaust
    3. Continued operation depends on simultaneous function of auxiliary systems, i.e.: induction, ignition, fuel, oil, cooling, exhaust.
- **c. Propeller:**
  - i. Rotating airfoil
  - ii. Provides thrust to pull A/C through air
  - iii. Amount of thrust produced depends on:
    1. Shape of airfoil
    2. AoA of airfoil
    3. RPM
- **d. Propeller Twist:**

i. Higher angle of incidence at hub than at tip
    1. Produces uniform lift from hub to tip
ii. Tip travels faster than hub
iii. Changing angle of incidence results in uniform lift throughout blade.

e. <u>Fixed-pitched propeller</u>

i. Pitch cannot be changed
ii. Most efficient at specific RPM and Airspeed
iii. <u>Two types</u>
    1. Climb prop
        a. Lower pitch angle = Less drag and Higher RPM
    2. Cruise prop
        a. Higher pitch angle = More drag and Lower RPM
iv. <u>Tachometer indicates engine power</u>
    1. Because prop is usually linked to crankshaft and they both rotate at the same rpm.
    2. Direct indication of engine and propeller RPM
    3. Green arc = max continuous operating RPM.
v. <u>Engine RPM is regulated by the throttle.</u>
    1. Fuel-to-air ratio control
vi. Because density decreases with altitude, throttle must be opened to indicate same RPM as in lower altitude.

f. <u>Constant-speed propeller</u>

i. Can provide higher thrust over a wider range of RPM
ii. Contains two controls
    1. Throttle – controls manifold pressure
    2. Propeller – controls RPM setting (Tachometer)
iii. RPM is maintained by the governor
    1. The governor adjusts the pitch of the propeller automatically to maintain the desired RPM setting.
iv. Manifold pressure gauge
    1. Measures manifold absolute pressure (MAP)
    2. Absolute pressure of the fuel/air mixture inside the intake manifold.
    3. Will measure ambient air pressure when the engine is off.
v. Each RPM has a maximum manifold pressure that should not be exceeded.
    1. Reduce manifold pressure before RPM
    2. Increase RPM before manifold pressure
    3. Most damage occurs @ High RPM and Low MP

B) Induction System

a. <u>Function:</u>

   i. Mixes air with Fuel

b. **Two types**
   i. Carburetor
   ii. Fuel injection

c. **Carburetor Systems:**
   i. Float type
      1. Air filtered → carburetor → venturi
      2. In ventui, low pressure airea is created.
         a. Forces fuel out of main fuel jet in carburetor throat.
         b. Mixes in air.
      3. Fuel/Air mixture goes through intake manifold and to the combustion chamber.
      4. Fuel float meters the correct amount of fuel into the carburetor, depending on the position
      5. Opens and closes a needle valve.
      6. Flow of fuel/air mix is regulated by the throttle valve and throttle.
   ii. Pressure type (not found in small GA)
      1. Uses fuel pump to distribute fuel under pressure

d. **Mixture control**
   i. Adjusts fuel/air mixture by restricting fuel flow into carburetor discharge nozzle.
   ii. Used to control for decrease in air density as airplane climbs
      1. Density of fuel does not change but air density does.
   iii. Excessively rich mixture
      1. carbon buildup due to effect of rich mixture lowering the temperature inside the cylinder and inhibiting complete combustion.
      2. Lean mixture!
   iv. Overly lean mixture
      1. Can happen during descent if mixture is not adjusted
      2. Can cause detonation, rough engine operation, overheating, and loss of power.
   v. Mixture can be used to:
      1. Lower/adjust engine temperature (fuel has a cooling effect)
      2. Gain better fuel economy
         a. Using EGT gauge.

e. **Carburetor Ice:**
   i. One disadvantage of float-type carburetors

ii. Caused by the cooling effect as vaporized fuel passes through the venturi causing a drop in pressure and temperature.
   1. Will form if water vapor is present and condenses when carburetor temperature is at or below freezing.

iii. Most likely to occur when temperature is below 70F(21C) and relative humidity is above 80%.
   1. However, due to sudden cooling, ice can form when temp is 100F(38C) and humidity 50%.

iv. Ice can form in throttle valve and throat.
   1. Restricts flow of fuel/air mixture and reduces power.
   2. If enough ice, engine can quit.

v. Particularly dangerous during a reduced power descent.

vi. Indications:
   1. Reduced RPM (in fixed pitch)
   2. Reduced MP (in constant speed props)

f. **Carburetor Heat:**

i. Anti-ice system

ii. Preheats air before reaching carburetor

iii. Used mostly as a preventative measure but can be used to melt some ice once formed.

iv. Should be checked at runup

v. Apply carb heat during closed throttle operations

vi. Carb heat causes a decrease in engine power, b/c the warm air decreases the air density in the combustion chamber.
   1. Do not use during takeoff.

vii. If ice is present you will notice a decrease in RPM following an increase in RPM after ice melts. (fixed pitch prop)

g. **Fuel Injection System:**

i. Fuel is injected directly into cylinders or slightly ahead of intake valve

ii. Less susceptible to ice

iii. Components
   1. Engine-driven fuel pump
   2. Fuel/air control unit (replaces carburetor)
   3. Discharge nozzle
   4. Auxiliary fuel pump
   5. Fuel manifold valve.

iv. Advantages

1. Reduction in evaporative icing
2. Better fuel flow
3. Faster throttle response
4. Precise control of mixture
5. Better fuel distribution
6. Easier cold weather starts

v. **<u>Disadvantages</u>**

1. Difficult starting a hot engine
2. Vapor lock during ground ops on hot days
3. Restarting engine that quits due to fuel starvation.

h. **<u>Superchargers</u>**

i. Engine-driven air pump or compressor that increases manifold pressure and forces fuel/air mixture into the cylinder.

ii. Higher manifold pressure → Higher density of fuel/ air mixture.

iii. Uses some engine power to operate.

iv. Operated via a gear system.

i. **<u>Turbochargers</u>**

i. Driven by engine exhaust gases

ii. Increases pressure of the engine induction air.

iii. <u>Has 2 main elements</u>

1. Turbine
2. Compressor

iv. <u>Also has a waste gate.</u>

1. Position of waste gate can be coupled to an actuator and pressure sensing mechanism or it can be manually controlled.
2. Manual waste gate systems can tend to overboost, advance throttle cautiously.
3. As A/C climbs we close the waste gate until reaching the critical altitude.

v. <u>Operations:</u>

1. Oil temp should be in the normal range and turbocharger should be allowed to cool down before shutting down the engine.
2. Oil must be supplied to bearings within the system for normal ops.

C) Ignition System

a. <u>Function:</u>

i. Provides the spark that ignites the fuel/air mixture in the cylinders.

b. Components:

i. **Magnetos**

1. Uses a permanent magnet to generate current independently of A/C electrical system
    a. Left magneto provides current to the lower left and upper right plug
    b. Right magneto provides current to the lower right and upper left plug
2. Begins to operate when starter is engaged and crankshaft begins to turn.
    a. Continues to operate whenever crankshaft is rotating.
3. Dual ignition improves combustion
    a. Means you have 2 spark plugs firing.
    b. Gives slightly higher power output.

ii. **Spark plug**

1. Provides electrical spark to ignite the fuel/air mixture in the cylinder.
2. High-tension leads

iii. **Ignition switch**

1. Controls operation of the magnetos and starter
2. Has 5 positions:
    a. Off
    b. R-Right Magneto
    c. L-Left Magneto
    d. Both
    e. Start

c. Operational Considerations:

i. **Mag Check**

1. Should observe drop in RPM during run-up not to exceed manufacturers specifications → check POH
2. Usually no more than 150 RPM drop per mag and no more than 75 RPM differential between mags.
3. If engine is rough when operated on one mag, attempt to clear the mag.
4. Lack of a drop in RPM is NOT normal.
5. Do not fly the A/C if RPM drop exceeds POH or AFM limits.

ii. **Magneto Ground Wire Check.**

1. Before shutdown, turn ignition switch to OFF momentarily to check for loose or broken wires in the ignition system.

D) Fuel System:

a. **<u>2 types:</u>**
   i. Gravity Feed – high wing A/C
   ii. Fuel Pump System – Low wing A/C

b. **<u>Location of Carburator</u>:**
   i. The carburetor is below the fuel tanks in the gravity feed system and above the fuel tanks in the fuel pump system.

c. **<u>Diagrams of the fuel Systems</u>:**
   i. [insert Gravity Feed and Fuel-Pump systems schematic here]

d. **<u>Components:</u>**
   i. Strainer:
      1. Removes moisture and other sediments
   ii. Sumps:
      1. Low points on the system where sediments and water could collect.
      2. We drain the fuel strainer and fuel sumps before each flight and after refueling.
      3. Wait 30 min after refueling to allow sedimentation.

E) Starter System:

a. **<u>General:</u>**
   i. Direct-cranking electrical starter system.

b. **<u>Components:</u>**
   i. Source of electricity
   ii. Wiring
   iii. Switches
   iv. Solenoids to operate starter
   v. Starter motor

c. **<u>Function:</u>**
   i. Battery supplies the electrical power for starting
   ii. When battery switch is turned on (Master Switch), the battery contactor solenoid energizes the main bus bar.
   iii. The starter and starter switch draw current from the main bus bar also, but the starter does not operate until the ignition is switched to "start" and the starter contactor solenoid engages which starts the starter.
   iv. Once "start" position is released, the starter is protected from being run by the engine through a starter clutch in the starter drive, which allows engine to run slightly faster than the starter.

F) Oil System:

a. **<u>Function:</u>**
   i. Lubrication
   ii. Cooling
      1. by reducing friction
      2. by absorbing heat from the cylinders
   iii. Seal between cylinder wall and piston
   iv. Carries away contaminants

b. **<u>Types:</u>**
   i. Dry-sump system
      1. Oil contained in separate tank external to engine
      2. Circulated through pumps
      3. More suitable for large reciprocating engines.
   ii. Wet Sump System
      1. Oil is located in a sump which is an integral part of the engine.
      2. Uses an oil pump to draw oil from sump and route it to the engine.
      3. Oil then returns to the sump.
      4. Crankshaft splashing provides additional lubrication.

c. **<u>Indications:</u>**
   i. High Oil Temp:
      1. Plugged oil line
      2. Low oil quantity
      3. Blocked oil cooler
      4. Defective temperature gauge
   ii. Low Oil Temp:
      1. Improper oil viscosity during cold weather ops.
      2. Faulty gauge.

d. **<u>Components:</u>**
   i. Oil sump, low pressure oil screen
   ii. Oil pump
   iii. High pressure oil screen
   iv. Oil cooler/filter
   v. Oil pressure relief valve
   vi. Oil filler cap and dipstick.
   vii. Oil pressure gauge
      1. Direct indication of oil system operation
      2. Measures pressure in lb/in^2
   viii. Oil temperature gauge
      1. Indicates temperature of oil
      2. Indication changes occur more slowly than pressure.

ix. System requires minimum oil quantity for correct operation
x. Check POH/AFM
xi. Also requires correct type and weight.

G) Engine Cooling System:

a. **Function**:
   i. Oil system provides internal cooling
   ii. Air cooling through engine baffles in engine compartment.
      1. Cools external surface of the engine.
      2. Route air through fins attached to cylinder heads
      3. Fins increase surface area exposed to cooling air.
   iii. Some A/C are liquid cooled.

b. **Considerations**:
   i. Ground operations can prevent effective cooling due to limited airflow.
   ii. High speed/rapid descents can shock-cool the engine
   iii. Abrupt temperature fluctuations can crack metal in the engine (i.e. cylinders).
   iv. Operating at high engine temperatures can cause:
      1. Loss of power
      2. Excessive oil consumption
      3. Detonation
      4. Scaring cylinder walls
      5. Damaging pistons and rings.
      6. Burning and warping the valves.

c. **Controlling engine temperature:**
   i. If no cowl flaps:
      1. Adjust power setting
      2. Adjust airspeed
      3. Adjust mixture
   ii. If cowl flaps:
      1. Open them on climbs, ground operations
      2. Close them during cruise, descents, and landings
      3. Cowl flaps allow more hot air to be routed out the engine compartment.
   iii. Oil temperature gauge gives indirect reading
   iv. Cylinder head temperature (CHT) shows direct and immediate cylinder temperature change.

H) Exhaust System:

a. **Function**:

i. Vent combustion gases overboard.
ii. Defrosts the windscreen
iii. Provides cabin heat
1. Outside air is ducted through the muffler shroud where it is heated and routed to the cabin.

b. **Considerations**:
i. Exhaust shroud must be checked for cracks to prevent CO poisoning.
1. CO present in large amounts of exhaust fumes
2. Odorless, colorless gas
3. Causes hypoxic-like symptoms and even death.

c. **Components**:
i. Exhaust piping attached to the cylinders
ii. Muffler
iii. Muffler Shroud.

d. **Operation**:
i. Exhaust is pushed out through exhaust valve in the cylinders then onto the exhaust piping and onto the atmosphere.
ii. EGT (Exhaust Gas Temperature)
iii. Temperature of gases in the exhaust manifold
iv. Varies with fuel-to-air ratio within the cylinder.

I) Electrical System:

a. **General**:
i. Either a 14 or 28-volt direct current electrical system

b. **Components**:
i. Alternator/Generator (Engine-driven)
ii. Battery
iii. Master/Battery Switch
iv. Alternator/Generator Switch
v. Bus Bar, fuses, and circuit breakers
vi. Voltage regulator
vii. Ammeter/Loadmeter
viii. Associated electrical wiring

c. **Alternator**:
i. Engine-driven
ii. Provide electrical current to electrical system
iii. Maintains sufficient electrical charge to the battery

d. **Battery**:
i. Provides electrical power to start the engine
ii. Provides small amount of backup electrical energy in the event of alternator or generator failure.

e. **Generator**:

i. Low output at low RPM
ii. Can deplete the battery
iii. Heavier
iv. Used more on large turbine-powered A/C.

Alternator	Generator
Provides sufficient electrical energy at all RPM setting	Low electrical output at low RPM
Produces alternating current (AC) which must be converted to direct current (DC)	Produces DC
More constant electrical output	Output varies by RPM
Lighter	Heavier

f. Bus Bar
- i. Connects equipment to electrically generating equipment
- ii. Acts as a terminal/electrical distribution
- iii. Simplifies the wiring

g. Fuses/Circuit Breaker
- i. Protects the circuit and equipment from electrical overload.
- ii. Circuit breaker can be manually reset
- iii. Fuses burn out and need to replace

h. **Ammeter**:
- i. Shows whether alternator is providing enough electrical output.
- ii. Indicates flow to the battery.
- iii. Some refer to it as a voltmeter\
- iv. Indications:
- v. (+) indication → charging rate to the battery
- vi. (-) indication → more current is being drawn from the battery than is being replaced
- vii. Full scale (-) deflection → Alternator failure
- viii. Full scale (+) deflection → Voltage regulator malfunctioning

i. **Loadmeter**:
- i. Shows load being placed on Alternator or Generator
- ii. Total % of load placed on the system

j. Voltage Regulator:
- i. Controls rate of charge to the battery

ii. Alternator output should be higher than the battery voltage to keep the battery fully charged.
iii. i.e., 14 volt alternator system keeping a 12-volt battery charged.

J) <u>Hydraulic System:</u>

a. **<u>Function</u>**:
   i. Brakes
   ii. Retractable landing gear
   iii. Some constant speed props
   iv. On large A/C:
      1. Flight control surfaces
      2. Wing flaps
      3. Spoilers
      4. Other systems.

b. **<u>Components</u>**:
   i. Hydraulic fluid reservoir
   ii. Pump (electrical or engine-driven)
   iii. Filter
   iv. Selector valve (control direction of flow)
   v. Pressure relief valve
   vi. Actuators

c. **<u>Operation</u>**:
   i. Hydraulic fluid is pumped through the system to an actuator or servo.
      1. Fluid can flow in either direction (172RG)
   ii. Landing gear:
      1. Hydraulic pressure moves the actuator which lowers or raises the gear.
   iii. Brakes:
      1. When brake pedal is pressed, hydraulic pressure through the brake lines provides pressure for the brake pads.

K) Pressurization:

a. **<u>Function</u>**:
   i. Maintains cabin pressure altitude of 8000ft @ max designed cruising altitude.
   ii. Prevents rapid changes of cabin altitude that may be uncomfortable or cause injury to passengers and crew.
   iii. Exchanges air from inside and outside.
   iv. Eliminates odors and removes stale air.

v. Protects passengers against the effects of hypoxia.

b. **<u>Components</u>**:
  i. Source of compressed air:
    1. Turbine
    2. Turbocharger
  ii. Outflow valve
    1. regulates air exit
  iii. Dump/Safety valve
  iv. Cabin pressure control system
    1. Provides:
      a. Cabin pressure regulation.
      b. Cabin pressure relief
      c. Vacuum relief
      d. Cabin altitude selection
    2. Made up of:
      a. Cabin pressure regulator
      b. Cabin differential pressure gauge
      c. Cabin altitude gauge
      d. Cabin rate of climb instrument

c. **<u>Decompression</u>**:
  i. <u>Explosive Decompression:</u>
    1. Occurs in less than 0.5 seconds.
    2. Faster than lungs can decompress
  ii. <u>Rapid Decompression:</u>
    1. Lungs can decompress faster than the cabin, so no lung damage.
  iii. <u>Dangers of Decompression:</u>
    1. Hypoxia
    2. Time of useful consciousness
    3. Should wear O2 masks above FL350.
    4. Tossed or blown out of the aircraft.
    5. Evolved gas decompression sickness.
    6. Exposure to wind blasts and extreme cold temperatures.

L) Supplemental Oxygen Systems

a. **<u>Components</u>**
  i. Container
  ii. 1800-2000 psi
  iii. Regulator
  iv. Mask outlet
  v. Pressure gauge

b. **<u>Types</u>**
  i. Fixed or Portable Systems

ii. Portable systems are not permanently attached or installed in the A/C.

iii. Diluter Demand:

1. Supplies O2 only when user inhales through the mask.
2. Automix
   a. Allows regulator to automatically mix cabin air and O2 or uses 100% O2 depending on altitude.
3. Demand mask:
   a. Provides tight seal
   b. Can be used up to 40,000ft.

iv. Pressure Demand:

1. O2 is supplied under pressure at cabin altitudes above 34,000ft.
2. Pressure demand regulators:
   a. Create air-tight, O2-tight seals
   b. Allows lungs to be pressurized with O2.
   c. Safe above 40,000ft.

v. Continuous Flow:

1. Re-breather bag.
2. O2 is continuously flowing
   a. Up to 25,000ft.
   b. Canulus up to 18,000ft
   c. Fits in nose.

c. <u>Dangers and Precautions:</u>

i. Must use aviation oxygen only which is 100% pure O2

1. Medical oxygen contains too much moisture which can freeze in the lines.

ii. Fire

1. Must keep it clean
2. Avoid smoking

iii. Thoroughly inspect and test.

1. Test the masks
2. Test the regulator and valve
3. Masks should be kept clean to avoid contamination and maintain hygiene.